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PATENT SPECIFICATION

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(54) SCREW-THREADED FASTENER

(71) We, YAMAMOTO BYORA COMPANY LIMITED, a Japanese corporation, of 2—2, 4-chome, Arakawa, Arakawa-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a screw-threaded fastener such as a bolt or screw and more particular to a fastener having a recess in one end thereof which is adapted to receive a fastener driving tool and which is provided on its inner peripheral wall with a plurality of ribs and grooves.

Already known is a screw provided with a slotted head or cross recessed head. However, such a screw has the drawbacks that the efficiency with which a force its transmitted from a driving tool to the screw is subject to limitation, and that the inner wall of the slot or cross recess is readily worn or damaged.

Further, a known bolt bearing a hexagonal recessed head has a relatively large "driving angle" of, for example, 60°. The "driving angle" is the angle between (a) a straight line radially extending from the centre of the bolt head through a force application point on the surface thereof and (b) the tangent to the surface of the screw driver at the force application point. This can cause the screw driver to slip and in consequence give rise to destruction of the inner wall of the head recess. Also, a large part of the applied force does not serve to drive the screw.

It is accordingly an object of this invention to obviate or mitigate the above disadvantages.

According to the present invention, there is provided a screw-thread fastener comprising a recess in one end thereof which is adapted to receive a fastener driving tool, the recess being provided on its inner peripheral wall with a plurality of ribs extending substantially parallel to the axis of the fastener and a plurality of grooves defined between the respective adjacent ribs, the cross-sectional profile of the outer surface of each groove comprising an arc of a first, common circle whose centre is situated substantially on the axis of the fastener, the cross-sectional profile of each rib being formed by an arc of a respective second circle which intersects said first circle, the centre of the respective second circle being disposed on or within the periphery of the first circle, each rib merging with each adjacent groove through the intermediary of a curved portion which, in cross-sectional profile, joins the rib at a point at which a radius of said first circle tangentially contacts the respective second circle or at a point further away from the centre of the first circle than said tangential contact point.

When subjected to a torque by a fastener driving tool having a cross-section corresponding to that of the recess, the driving angle is reduced to zero and the fastener of this invention is saved from any component force which possibly gives rise to slipping of the driving tool. Therefore, the torque applied to the driving tool is transmitted efficiently to the fastener, causing neither damage or wear of the latter. Also, the driving tool does not ride out of the recess.

For practical purposes, the centre of each second circle preferably lies between the periphery of the first circle and a chord connecting the points of inter-section between the first circle and the respective second circle.

Even when the centre of the respective second circle is positioned nearer the centre of the first circle than the above-mentioned chord, the driving angle can still be reduced to zero. In this case, however, those portions of each rib and each adjacent groove which are immediately adjacent the respective curved portion therebetween include an acute angle, thereby undesirably narrowing the opening of each groove between the adjacent ribs.

As stated above, in the fastener of the present invention, each rib merges with each adjacent groove through the intermediary of a curved portion. This eliminates what would

otherwise be an angular corner between each rib and each adjacent groove, thereby reducing the risk of damage to the fastener.

The ribs are preferably provided equidistantly on the inner peripheral wall of the recess, with the diameter d_0 of each second circle being defined by the formula:

$$\frac{1}{2}\cdot\frac{\pi}{n}D_0 \leqslant d_0 \leqslant \frac{4}{5}\cdot\frac{\pi}{n}D_0 \qquad (1)$$

where n is the number of ribs and D_0 is the diameter of the first circle.

Where all of the force applied by the driving tool is transmitted to a fastener satisfying the above formula, neither the fastener nor the driving tool is subject to any damage for the reason given below.

The materials from which a screw-threaded fastener (such as a bolt or screw) and a fastener driving tool are made have a tensile strength generally specified to fall within the ranges of 45 to 180 kg/mm² and 120 to 180 kg/mm², respectively. The shearing strength of such materials, particularly steel, is generally proportional to its tensile strength. The ratio which the shearing strength of the material of the fastener bears to that of the driving tool lies between 1.5:1 and 1:4. Since the fastener does not normally have a larger shearing strength than the driving tool, the above-mentioned range may be regarded to extend from 1:1 to 1:4. It is seen from this fact that, where the width of each rib in the recess bears a ratio ranging between 1:1 and 4:1 to that of a lobe of the driving tool which engages a groove between the respective ribs, then both rib and lobe have an equal shearing resistance. Since the width L of each rib of the fastener approximates to the diameter d_0 of the respective second circle, the rib width L and the width l_1 of the lobe of the driving tool have the following relationship:

$$l_1 \leqslant L \doteqdot d_0 \leqslant 4l_1 \qquad (2)$$

On the other hand, the width l_1 of the lobe of the driving tool is substantially equal to the width l_0 of each groove of the fastener, which in turn approximates to the length of each arc of the first circle defined between the respective ribs. Therefore, the width l_1 of the lobe of the driving tool may be expressed by the following formula:

$$l_1 \doteqdot \frac{\pi}{n}D_0 - d_0 \qquad (3)$$

The previously mentioned formula (1) is derived from the formulae (2) and (3).

Since the shearing strengths of the fastener and the driving tool most often used in practice have a ratio ranging between 1:2 and 1:3, it is advisable to define the diameter of each second circle as expressed by the following formula:

$$\frac{2}{3}\cdot\frac{\pi}{n}D_0 \leqslant d_0 \leqslant \frac{3}{4}\cdot\frac{\pi}{n}D_0 \qquad (4)$$

As viewed vertically of the fastener, the peripheral surface of each rib is preferably tapered inwardly at an angle of 1° to 10° to the axis of the fastener, and slightly more than the inner wall of the corresponding groove of the driving tool. This arrangement enables a punching tool to be easily released from the recess of the fastener when it is manufactured, and also enables the fastener and the driving tool to be firmly engaged with each other.

It is desirable to provide four to eight, particularly six ribs on the inner peripheral wall of the recess. If fewer than four ribs are provided, then difficulties will arise in quickly locating the driving tool with respect to the recess. Conversely, where more than eight ribs are provided, the ribs will be decreased in size and will be readily worn, and moreover errors will probably occur in the dimensions and positions of the ribs when the fastener is fabricated.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figs. 1 and 2 are respectively a plan view and an elevational view of a first embodiment of a screw-threaded fastener according to the present invention, in the form of a screw;

Figs. 3 and 4 are respectively a bottom view and a fractional elevational view of a driving tool engageable with a recess in the fastener of Figs. 1 and 2;

Fig. 5 is a cross-sectional view of the driving tool of Figs. 3 and 4 engaged with the recess in the fastener of Figs. 1 and 2;

Fig. 6 is a schematic illustration of another embodiment of the fastener of Figs. 1 and 2;

Fig. 7 is a schematic plan view of the fastener of Figs. 1, 2 and 5 showing ribs thereof in detail;

Fig. 8 is a sectional view on line 8—8 of Fig. 5;

Fig. 9 is a diagram showing the relationship between the angles of taper of a rib of the fastener and of a corresponding part of a driving tool;

Figs. 10A to 10D are respective plan views of further embodiments of a fastener according to the present invention; and

Figs. 11A to 11D are respective fractional elevational views of the fasteners of Figs. 10A to 10D.

Referring to Figs. 1 and 2, the screw 10

of this invention has a plain head 12 having a recess 11 therein and a threaded shank 13 coaxial with the recess 11 extending downward from the underside of the head 12. Six ribs 14 are equidistantly provided on the inner peripheral wall of the recess 11, a groove 15 being defined between each pair of adjacent ribs 14. The lower portion of the recess 11 is formed, as is apparent from Figs. 2 and 8, in an inverted conical shape. The rib 14, the cross-section profile of which comprises an arc of a circle 16, extends from the top of the head 12 to the bottom of the recess 11. The outer surface of each groove 15, namely, that portion of the inner peripheral wall of the recess 11 which is disposed between the respective ribs, in cross-sectional profile comprises an arc of a larger circle 17.

A driving tool, in the form of a screw driver 18, is shown in Figs. 3 and 4 has a plurality of grooves 19 engageable with the ribs 14 of the recess 11 and a plurality of lobes 20 engageable with the grooves 15 of the recess 11, the cross-section of the screw driver 18 being substantially complementary to that of the recess 11. In use, the screw driver 18 is driven by a lever (not shown) to apply a torque to the screw head 12.

When a torque is transmitted from the screw driver 18 to the screw 10, it is important to pay attention to the "driving angle" which is, as previously mentioned, the angle defined between (a) a straight line extending radially from the centre 0 of the circle 17 through a force application point F (Fig. 5) (at which the lobes 20 of the screw driver 18 apply a force to the ribs 14 of the screw head recess 11) and (b) the tangent to the respective circle 16 at the force application point F. The ribs 14 of the recess 11 are so shaped as to reduce the "driving angle" substantially to zero. In the embodiment of Figs. 1, 2 and 5, the centre O_1 of each circle 16 is situated on the periphery of the circle 17. In this case, the tangent to each circle 16 at the force application point F is substantially aligned with a straight line $\overline{OF}$, reducing the "driving angle" substantially to zero.

The centre O_1 of each circle 16 in the embodiment of Fig. 6 falls on a chord 22 connecting the points P of intersection between that circle 16 and the circle 17. Since the recess 11 and screw driver 18 may be regarded as having substantially the same cross-sectional form, the outlines of both cross-sections are indicated by a common line in Fig. 6. The tangent to the circle 16 at the force application point is also aligned with a straight radial line OF. In addition, each straight radial line OF coincides with a tangent to the respective circle 16, reducing the driving angle to zero. In consequence, all of the force applied to the screw driver 18 is transmitted to the screw without the occurrence of any component force leading to slipping or riding out of the screw driver.

As is shown in detail in Fig. 7, each rib merges with each adjacent groove through the intermediary of a curved portion whose cross-sectional profile comprises an arc $23a$ of an imaginary small circle 23 at the base of the rib. This arrangement eliminates what would otherwise be an angular corner on the inner peripheral wall of the recess 11, thereby minimizing damage to or wear of the ribs 11 when the fastener is fabricated or a torque is transmitted thereto from a driving tool. As viewed in cross-section, each curved portion joins the respective rib at a point at which a radius of the circle 17 tangentially contacts the respective second circle 16, or at a point further away from the centre O of the circle 17 than said tangential contact point. If the centre O_1 of each circle 16 were to be situated exactly on the point of intersection between the tangents to the circle 17 at the points P of intersection between the circle 17 and that circle 16, it would be impossible to provide a curved portion between each rib and each adjacent groove and still arrange for the driving angle to be zero, i.e. such that almost all of the force applied at that point is transmitted to the screw. If the centre O_1 of each circle 16 were to be situated closer to the centre O of the circle 17 than the tangent intersection point but outside the periphery of the circle 17, the curved portions would be very small.

Since, as previously mentioned, the width l_1 of each lobe 20 of the driving tool is substantially equal to the width l_0 of each groove 15 of the screw, it is preferred to set the ratio of the width L of each rib 14 of the screw to the width l_0 of each groove 15 within the range 1:1 to 4:1, most preferably 2:1 to 3:1, in order to equalize the shearing resistance of the ribs 14 of the screw with that of the lobes 20 of the driving tool.

Referring again to Fig. 5, since the width L of each rib 14 is substantially equal to the diameter d_0 of the respective circle 16, the following formula results:

$$l_0 \leqslant L \doteqdot d_0 \leqslant 4l_0$$

and preferably

$$2l_0 \leqslant d_0 \leqslant 3l_0$$

On the other hand, the width l_0 of each groove 15 is substantially equal to the length of a respective arc of the circle 17 defined between the circles 16 of the respective two adjacent ribs 14, six grooves 15 are provided, and the circle 17 has a diameter D_0. Accordingly, the width l_0 of each groove 15 may be expressed by the following formula:

$$l_0 \doteqdot \frac{1}{6}\pi D_0 - d_0$$

Throughout the foregoing embodiments, therefore, the diameter d_0 of each circle 16 is defined as follows:

$$\frac{1}{12}\pi D_0 \leqslant d_0 \leqslant \frac{2}{15}\pi D_0$$

and preferably

$$\frac{1}{9}\pi D_0 \leqslant d_0 \leqslant \frac{1}{8}\pi D_0$$

With the diameter d_0 of each circle 16 being as given above, the ribs 14 of the screw and the lobes 20 of the driving tool have a substantially equal shearing resistance and are saved from any damage, even when all of the force applied to the driving tool is transmitted to the screw 10.

Referring to Fig. 8, the peripheral surfaces of the ribs 14 taper inwardly at an angle α to the axis O—O of the screw. On the other hand, the inner peripheral walls of the grooves 19 of the driving tool 18 taper inwardly at an angle β to the axis O—O of the driving tool 18. In this case, the angles α and β are specified to have the following relationship:

$$\alpha \geqslant \beta$$

Further, the minimum distance L_0 between the apex of each rib 14 of the screw and the axis O—O bears following relationship to the minimum distance L_1 between the bottom wall of each groove 19 of the driving tool and the axis O—O:

$$L_0 \leqslant L_1$$

Therefore, the depth Q to which the driving tool 18 is driven into the recess 11 in the screw has the following relationship with the depth H of said recess:

$$Q \leqslant H$$

Accordingly, the bottom end of each groove 19 of the driving tool firmly engages the respective rib 14 of the screw at a point S. Throughout the foregoing embodiments, the above-mentioned taper angle α of the ribs 14 is defined as follows:

$$1° \leqslant \alpha \leqslant 10°$$

and preferably

$$1° \leqslant \alpha \leqslant 7°$$

Referring to Fig. 9, with a force (designated as N) acting at right angles to the interface between each rib 14 of the screw and the respective groove 19 of the driving tool, a coefficient of static friction μ, and the dead weight of the screw 10 equal to W, then the following formula must be satisfied to prevent the screw 10 from gravitationally falling off the driving tool 18.

$$\mu N \cos \alpha > N \sin \alpha + W$$

therefore,

$$\mu > \tan \alpha + \frac{W}{N} \sec \alpha$$

Since, in this case $N >> W$ and $\sec \alpha \doteqdot 1$ if α is taken to have a small value, the following formula results:

$$\mu > \tan \alpha$$

Namely, the requisite condition for the screw 10 to be firmly engaged with the driving tool 18 without falling off under the action of gravity is than $\tan \alpha$ should be smaller than the coefficient μ of static friction. Steel-to-steel static friction coefficient μ ranges from 0.15 to 0.25 when the friction surface is dry, and from 0.14 to 0.18 when oil is attached to said friction surface.

Therefore,

$$\tan \alpha < 0.18,$$

and preferably

$$\tan \alpha < 0.14$$

$$\therefore \alpha \leqslant 10°$$

and preferably

$$\alpha \leqslant 7°$$

Since an unduly small taper angle α of the peripheral surface of the ribs 14 of the screw presents difficulties in releasing the driving tool 18 from the screw 10, the taper angle α is preferred to be greater than or equal to 1°.

Throughout the foregoing embodiments, the peripheral surfaces of the ribs 14 of the screw and the inner surfaces of the grooves 19 of the driving tool are designed to engage each other when the driving tool is inserted into the recess in the screw. However, it is possible to taper the peripheral walls of the grooves 15 of the screw and the outer surface of the lobes 20 of the driving tool similarly at angles of α and β respectively for concurrent mutual engagement.

The fastener of Figs. 10A and 11A is a screw 26 having a flat fillister head 25; the

fastener of Figs. 10B and 11B is a headless set screw 28 consisting of a threaded shank 27; the fastener of Figs. 10C and 11C is a screw 30 with a flanged head 29; and the fastener of Figs. 10D and 11D is a screw 32 with a pan head 31. These screws 26, 28, 30, 32 are provided with recesses 11*a*, 11*b*, 11*c*, 11*d* respectively which are of the same type as the recess 11 of Figs. 1, 2 and 5 to 8.

WHAT WE CLAIM IS:—

1. A screw-threaded fastener having a recess in one end thereof which is adapted to receive a fastener driving tool, the recess being provided on its inner peripheral wall with a plurality of ribs extending substantially parallel to the axis of the fastener and a plurality of grooves defined between the respective adjacent ribs, the cross-sectional profile of the outer surface of each groove comprising an arc of a first, common circle whose centre is situated substantially on the axis of the fastener the cross-sectional profile of each rib being formed by an arc of a respective second circle which intersects said first circle, the centre of the respective second circle being disposed on or within the periphery of the first circle, each rib merging with each adjacent groove through the intermediary of a curved portion which, in cross-sectional profile, joins the rib at a point at which a radius of said first circle tangentially contacts the respective second circle or at a point further away from the centre of the first circle than said tangential contact point.

2. A fastener as claimed in Claim 1, wherein the centre of the respective second circle is disposed between the periphery of the first circle and a chord connecting the points of intersection between the first circle and the respective second circle.

3. A fastener as claimed in Claims 1 or 2, wherein the ribs are equidistantly provided on the inner peripheral wall of the recess, and the diameter d_0 of each second circle is defined by the formula:

$$\frac{1}{2} \cdot \frac{\pi}{n} D_0 \leqslant d_0 \leqslant \frac{4}{5} \cdot \frac{\pi}{n} D_0$$

where n is the number of ribs, and D_0 is the diameter of the first circle.

4. A fastener as claimed in Claim 3, wherein the diameter d_0 of each second circle is defined by the formula:

$$\frac{2}{3} \cdot \frac{\pi}{n} D_0 \leqslant d_0 \leqslant \frac{3}{4} \cdot \frac{\pi}{n} D_0$$

5. A fastener as claimed in any preceding Claim, wherein the peripheral surface of each rib tapers inwardly with respect to the fastener axis at an angle α defined by the formula:

$$1° \leqslant \alpha \leqslant 10°$$

6. A fastener as claimed in Claim 5, wherein the peripheral surface of each rib tapers inwardly with respect to the fastener axis at an angle α defined by the formula:

$$1° \leqslant \alpha \leqslant 7°$$

7. A fastener as claimed in any preceding Claim, wherein between four and eight ribs are provided.

8. A fastener as claimed in Claim 7, wherein six ribs are provided.

9. A fastener as claimed in any preceding Claim, comprising a head and a screw-threaded shank, and wherein the recess is formed in the head and the shank extends co-axially with respect to the recess.

10. A fastener as claimed in Claim 9, wherein the head is of a plain type.

11. A fastener as claimed in Claim 9, wherein the head is of a flat fillister type.

12. A fastener as claimed in Claim 9, wherein the head is of a flanged type.

13. A fastener as claimed in Claim 9, wherein the head is of a pan type.

14. A fastener as claimed in any one of Claims 1 to 8 in the form of a headless set screw.

15. A fastener as claimed in any preceding Claim, wherein the cross-sectional profile of each curved portion is an arc of a respective circle.

16. A fastener substantially as hereinbefore described with reference to Figs. 1, 2, 5, 7, 8 and 9, or Figs. 1, 2, 5, 7, 8 and 9 as modified by Fig. 6, or Figs. 10A and 11A, or Figs. 10B and 11B, or Figs. 10C and 11C, or Figs. 10D and 11D of the accompanying drawings.

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1491515 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG. 1

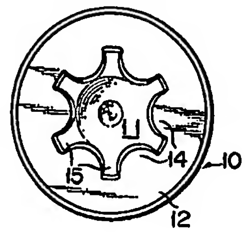


FIG. 3

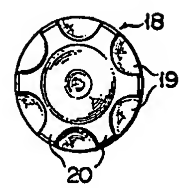


FIG. 2

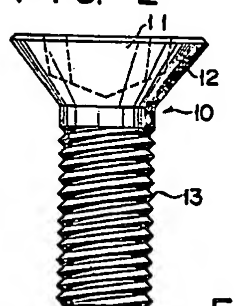


FIG. 4

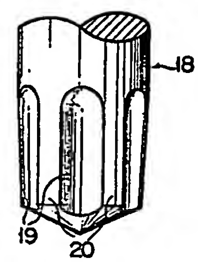


FIG. 5

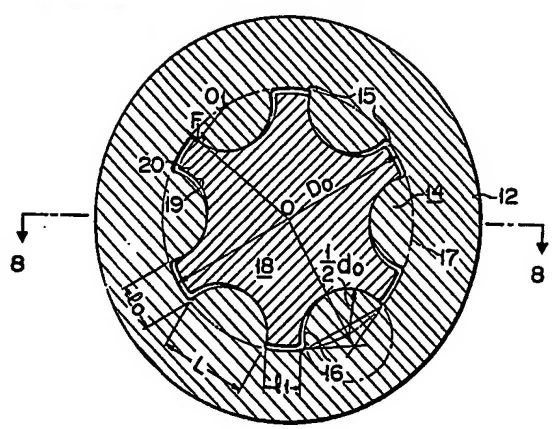


FIG. 6

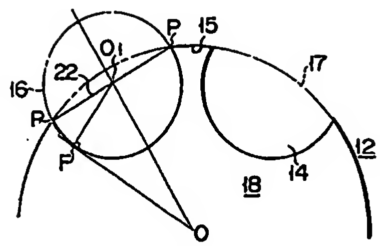


FIG. 7

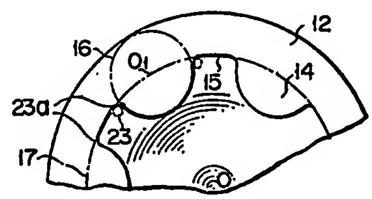


FIG. 9

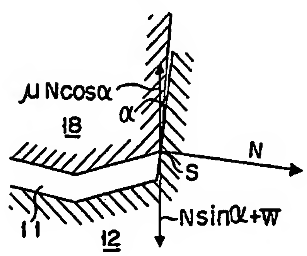


FIG. 10A

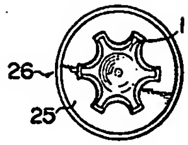


FIG. 10B

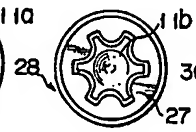


FIG. 10C

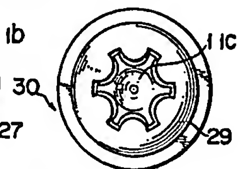
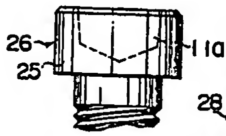


FIG. 11A



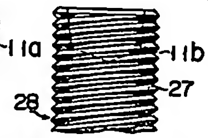


FIG. 11B

FIG. 11C

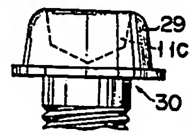


FIG. 10D

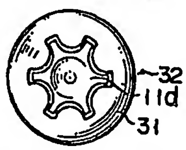


FIG. 11D

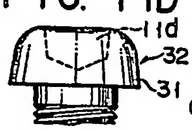


FIG. 8